SN54LS668, SN54LS669, SN74LS668, SN74LS669
SYNCHRONOUS 4-BIT UP/DOWN COUNTERS

SDLS192 – APRIL 1977 – REVISED MARCH 1988

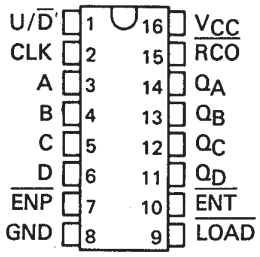
'LS668 . . . SYNCHRONOUS UP/DOWN DECADE COUNTERS
'LS669 . . . SYNCHRONOUS UP/DOWN BINARY COUNTERS

Programmable Look-Ahead Up/Down Binary/Decade Counters

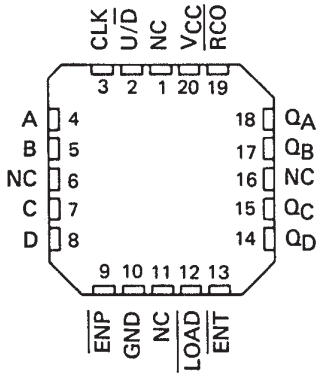
- **Fully Synchronous Operation for Counting and Programming**
- **Internal Look-Ahead for Fast Counting**
- **Carry Output for n-Bit Cascading**
- **Fully Independent Clock Circuit**
- **Buffered Outputs**

TYPE	TYPICAL MAXIMUM CLOCK FREQUENCY		TYPICAL POWER DISSIPATION
	COUNTING UP	COUNTING DOWN	
'LS668, 'LS669	32 MHz	32 MHz	100 mW

SN54LS668, SN54LS669 . . . J OR W PACKAGE
SN74LS668, SN74LS669 . . . D OR N PACKAGE
(TOP VIEW)



SN54LS668, SN54LS669 . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection

description

These synchronous presettable counters feature an internal carry look-ahead for cascading in high-speed counting applications. The 'LS668 are decade counters and the 'LS669 are 4-bit binary counters. Synchronous operation is provided by having all flip-flops clocked simultaneously so that the outputs change coincident with each other when so instructed by the count-enable inputs and internal gating. This mode of operation helps eliminate the output counting spikes that are normally associated with asynchronous (ripple-clock) counters. A buffered clock input triggers the four master-slave flip-flops on the rising (positive-going) edge of the clock waveform.

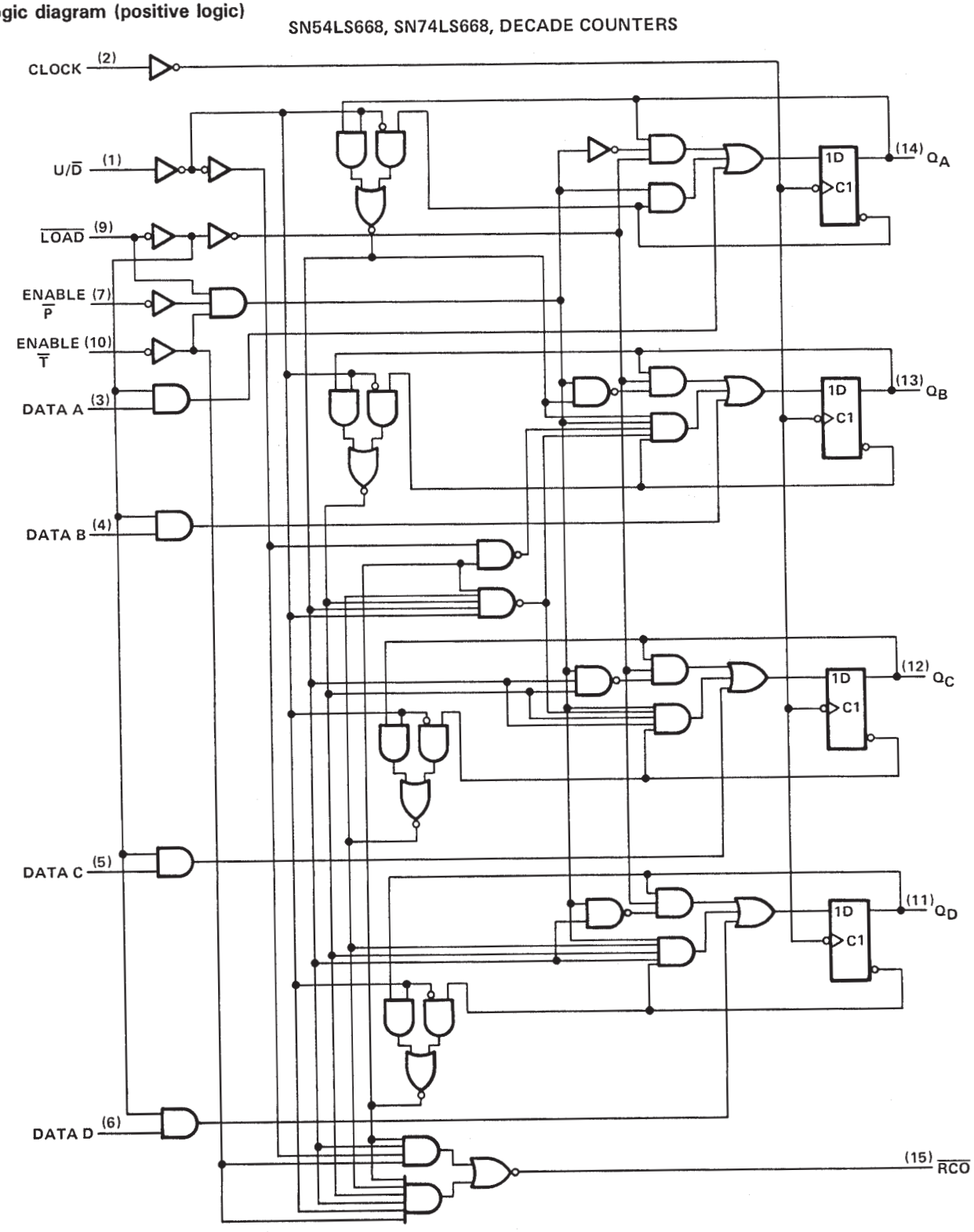
These counters are fully programmable; that is, the outputs may each be preset to either level. The load input circuitry allows loading with the carry-enable output of cascaded counters. As loading is synchronous, setting up a low level at the load input disables the counter and causes the outputs to agree with the data inputs after the next clock pulse.

The carry look-ahead circuitry provides for cascading counters for n-bit synchronous applications without additional gating. Instrumental in accomplishing this function are two count-enable inputs and a carry output. Both count enable inputs ($\overline{P}$ and $\overline{T}$) must be low to count. The direction of the count is determined by the level of the up/down input. When the input is high, the counter counts up; when low, it counts down. Input $\overline{T}$ is fed forward to enable the carry output. The carry output thus enabled will produce a low-level output pulse when the count is maximum counting up or zero counting down. This low-level overflow carry pulse can be used to enable successive cascaded stages. Transitions at the enable $\overline{P}$ or $\overline{T}$ inputs are allowed regardless of the level of the clock input. All inputs are diode-clamped to minimize transmission-line effects, thereby simplifying system design.

These counters feature a fully independent clock circuit. Changes at control inputs (enable $\overline{P}$, enable $\overline{T}$, load, up/down) that will modify the operating mode have no effect until clocking occurs. The function of the counter (whether enabled, disabled, loading, or counting) will be dictated solely by the conditions meeting the stable setup and hold times.

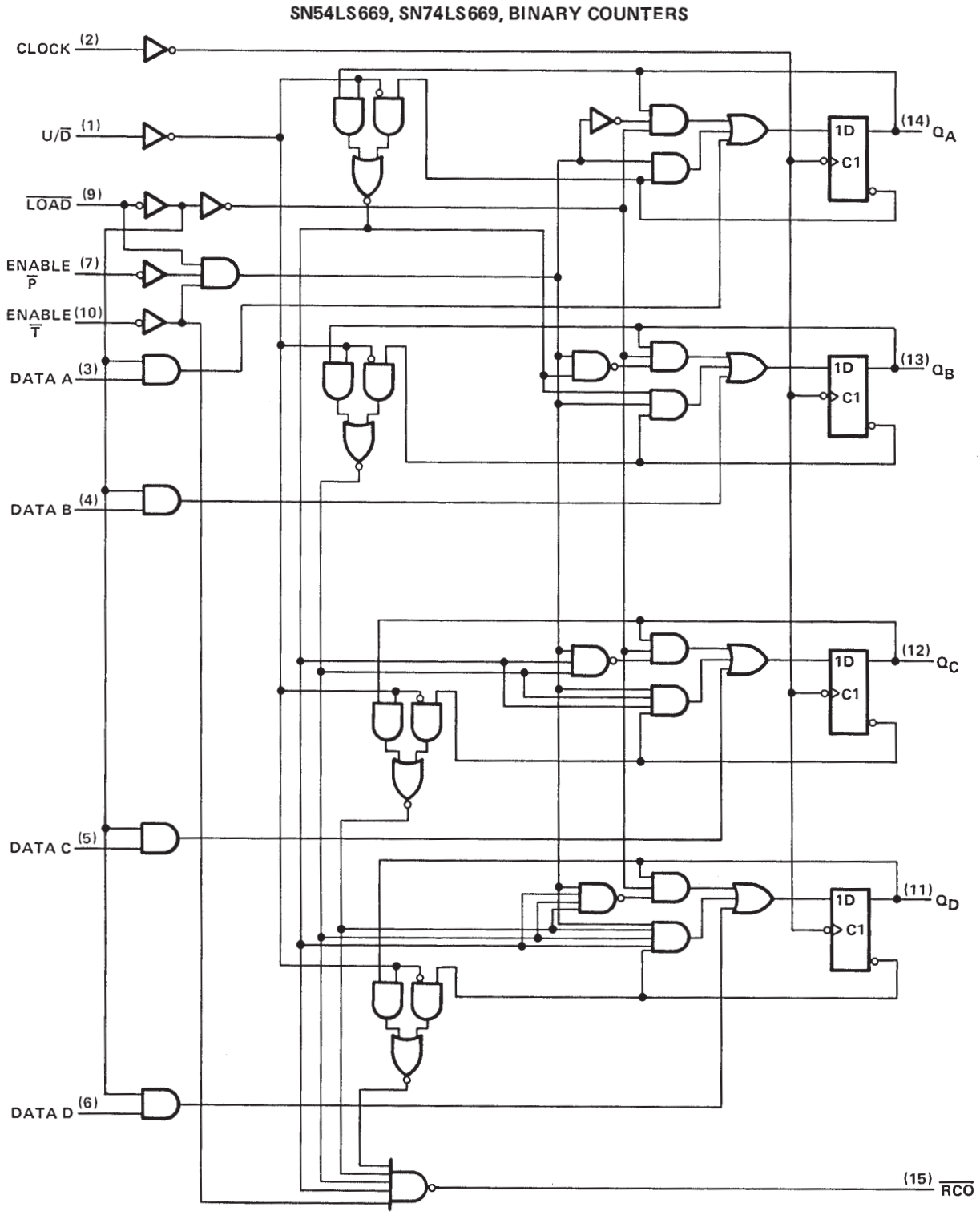
The 'LS668 and 'LS669 are completely new designs. Compared to the original 'LS168 and 'LS169, they feature 0-nanosecond minimum hold time, reduced input currents I_{IH} and I_{IL}, and all buffered outputs.

logic diagram (positive logic)



Pin numbers shown are for D, J, N, and W packages.

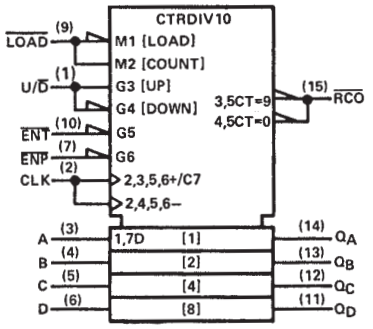
logic diagram (positive logic) (continued)



Pin numbers shown are for D, J, N, and W packages.

'LS668 DECADE COUNTERS

logic symbol†

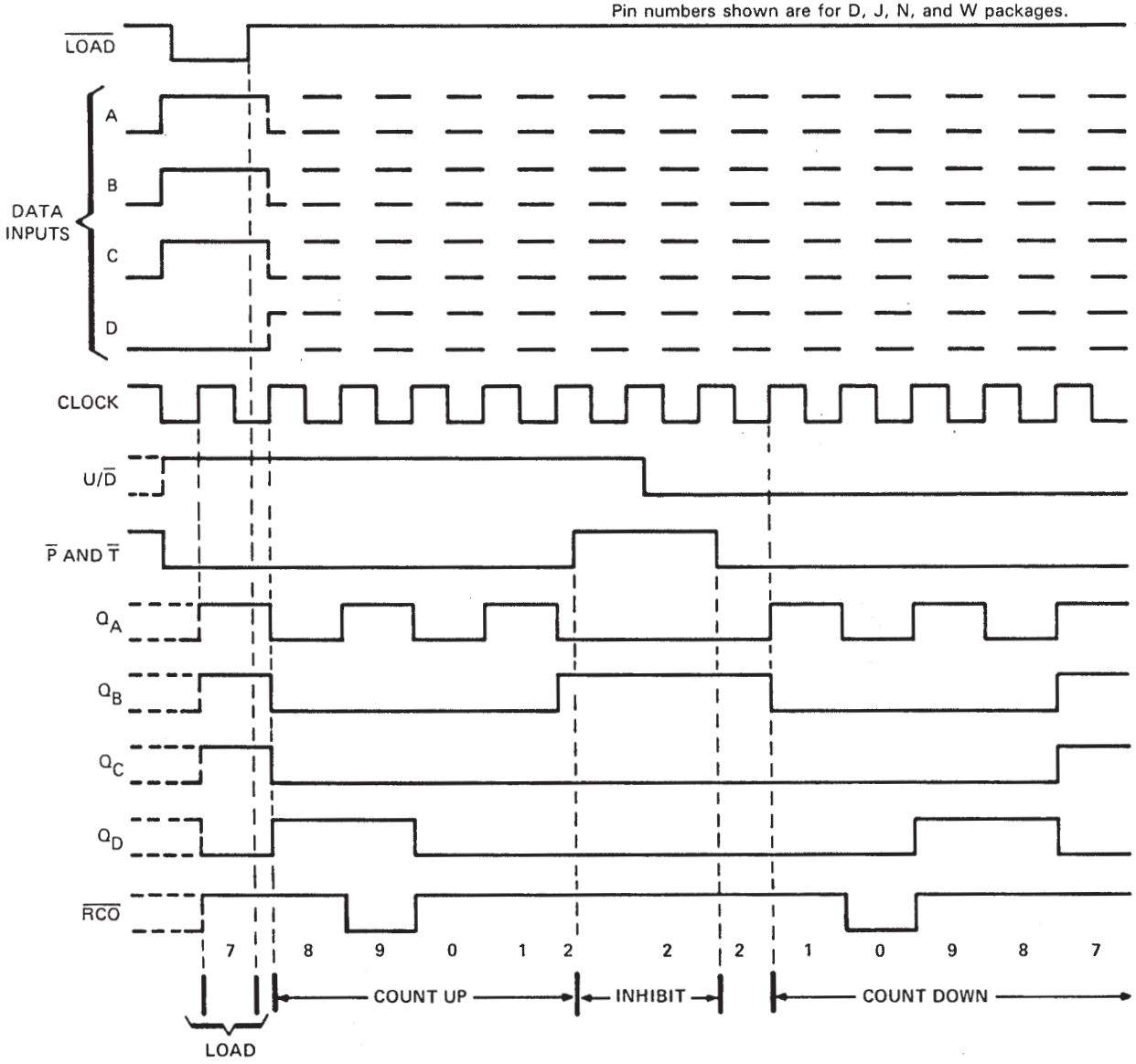


†This symbol is in accordance with ANSI/IEEE Std. 91-1984 and IEC Publication 617-12.
Pin numbers shown are for D, J, N, and W packages.

typical load, count, and inhibit sequences

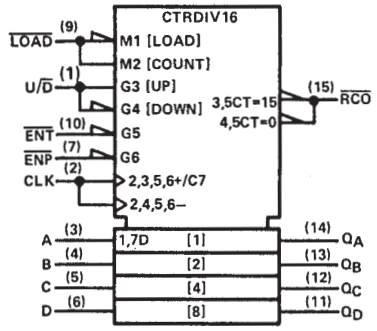
Illustrated below is the following sequence:

1. Load (preset) to BCD seven
2. Count up to eight, nine (maximum), zero, one, and two
3. Inhibit
4. Count down to one, zero (minimum), nine, eight, and seven



'LS669 BINARY COUNTERS

logic symbol†

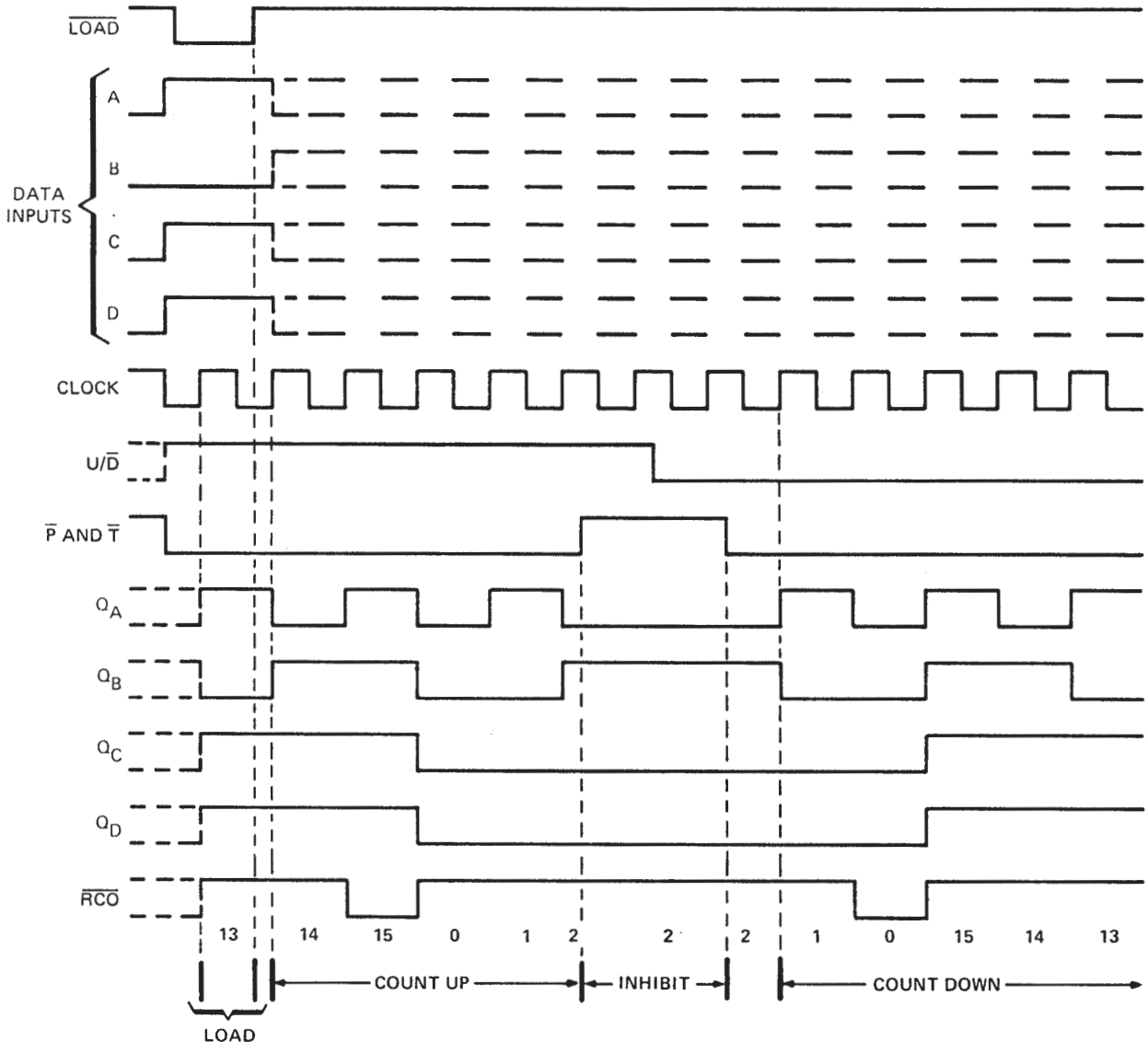


†This symbol is in accordance with ANSI/IEEE Std. 91-1984 and IEC Publication 617-12.
Pin numbers shown are for D, J, N, and W packages.

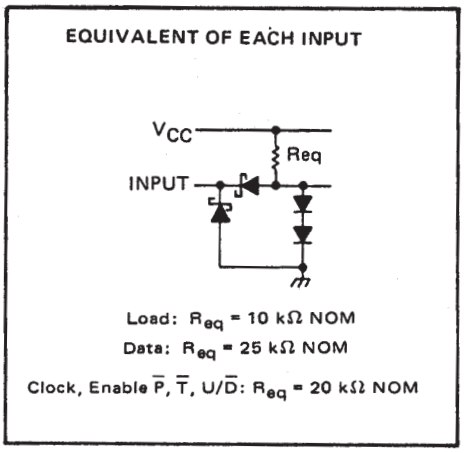
typical load, count, and inhibit sequences

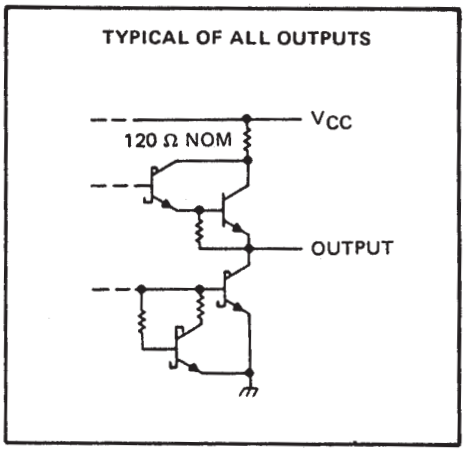
Illustrated below is the following sequence:

1. Load (preset) to binary thirteen
2. Count up to fourteen, fifteen (maximum), zero, one, and two
3. Inhibit
4. Count down to one, zero (minimum), fifteen, fourteen, and thirteen



schematics of inputs and outputs





absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V_{CC} (see Note 1) . . . . . 7 V
Input voltage . . . . . 7 V
Operating free-air temperature range: SN54LS668, SN54LS669 . . . . . −55°C to 125°C
SN74LS668, SN74LS669 . . . . . 0°C to 70°C
Storage temperature range . . . . . −65°C to 150°C

NOTE 1: Voltage values are with respect to network ground terminal.

recommended operating conditions

		SN54LS668 SN54LS669			SN74LS668 SN74LS669			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{CC}		4.5	5	5.5	4.75	5	5.25	V
High-level output current, I_{OH}				−400			−400	μA
Low-level output current, I_{OL}				4			8	mA
Clock frequency, f_{clock}		0		25	0		25	MHz
Width of clock pulse, $t_{w(clock)}$ (high or low) (see Figure 1)		20			20			ns
Setup time, t_{su} (see Figure 1)	Data inputs A, B, C, D	25			25			ns
	$\overline{ENP}$ or $\overline{ENT}$	40			40			
	$\overline{LOAD}$	30			30			
	$U/\overline{D}$	45			45			
Hold time at any input with respect to clock, t_h (see Figure 1)		0			0			ns
Operating free-air temperature, T_A		−55		125	0		70	°C

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER			TEST CONDITIONS†		SN54LS668 SN54LS669			SN74LS668 SN74LS669			UNIT
					MIN	TYP‡	MAX	MIN	TYP‡	MAX	
V_{IH}	High-level input voltage				2			2			V
V_{IL}	Low-level input voltage						0.7			0.8	V
V_{IK}	Input clamp voltage		V_{CC} = MIN,	I_I = −18 mA			−1.5			−1.5	V
V_{OH}	High-level output voltage		V_{CC} = MIN, V_{IL} = V_{IL} max,	V_{IH} = 2 V, I_{OH} = −400 μA	2.5	3.4		2.7	3.4		V
V_{OL}	Low-level output voltage		V_{CC} = MIN, V_{IH} = 2 V, V_{IL} = V_{IL} max	I_{OL} = 4 mA		0.25	0.4		0.25	0.4	V
				I_{OL} = 8 mA					0.35	0.5	
I_I	Input current at maximum input voltage	A, B, C, D, $\overline{P}$, U/$\overline{D}$	V_{CC} = MAX,	V_I = 7 V			0.1			0.1	mA
		Clock, $\overline{T}$					0.1			0.1	
		$\overline{LOAD}$					0.2			0.2	
I_{IH}	High-level input current	A, B, C, D, $\overline{P}$, U/$\overline{D}$	V_{CC} = MAX,	V_I = 2.7 V			20			20	μA
		Clock, $\overline{T}$					20			20	
		$\overline{LOAD}$					40			40	
I_{IL}	Low-level input current	A, B, C, D, $\overline{P}$, U/$\overline{D}$	V_{CC} = MAX,	V_I = 0.4 V			−0.4			−0.4	mA
		Clock, $\overline{T}$					−0.4			−0.4	
		$\overline{LOAD}$					−0.8			−0.8	
I_{OS}	Short-circuit output current§		V_{CC} = MAX		−20		−100	−20		−100	mA
I_{CC}	Supply current		V_{CC} = MAX,	See Note 2		20	34		20	34	mA

†For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡All typical values are at V_{CC} = 5 V, T_A = 25°C.
§Not more than one output should be shorted at a time, and duration of the short-circuit should not exceed one second.
NOTE 2: I_{CC} is measured after applying a momentary 4.5 V, then ground, to the clock input with all other inputs grounded and the outputs open.

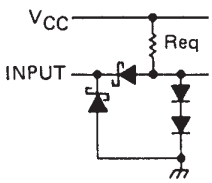
switching characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER¶	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
f_{max}			C_L = 15 pF, R_L = 2 kΩ, See Figures 2 and 3	25	32		MHz
t_{PLH}	CLK	$\overline{RCO}$			26	40	ns
t_{PHL}					40	60	
t_{PLH}	CLK	Any Q			18	27	ns
t_{PHL}					18	27	
t_{PLH}	$\overline{ENT}$	$\overline{RCO}$			11	17	ns
t_{PHL}					29	45	
t_{PLH}#	U/$\overline{D}$	$\overline{RCO}$			22	35	ns
t_{PHL}#					26	40	

¶ f_{max} = Maximum clock frequency.
t_{PLH} = propagation delay time, low-to-high-level output.
t_{PHL} = propagation delay time, high-to-low-level output.
Propagation delay time from up/down to ripple carry must be measured with the counter at either a minimum or a maximum count. As the logic level of the up/down input is changed, the ripple carry output will follow. If the count is minimum (0), the ripple carry output transition will be in phase. If the count is maximum (9 for 'LS668 or 15 for 'LS669), the ripple carry output will be out of phase.

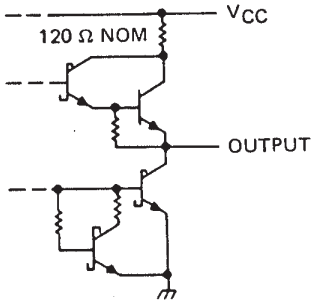
schematics of inputs and outputs

EQUIVALENT OF EACH INPUT



Load: R_{eq} = 10 kΩ NOM
Data: R_{eq} = 25 kΩ NOM
Clock, Enable $\overline{P}$, $\overline{T}$, U/$\overline{D}$: R_{eq} = 20 kΩ NOM

TYPICAL OF ALL OUTPUTS



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V_{CC} (see Note 1) . . . . . 7 V
Input voltage . . . . . 7 V
Operating free-air temperature range: SN54LS668, SN54LS669 . . . . . −55°C to 125°C
SN74LS668, SN74LS669 . . . . . 0°C to 70°C
Storage temperature range . . . . . −65°C to 150°C

NOTE 1: Voltage values are with respect to network ground terminal.

recommended operating conditions

		SN54LS668 SN54LS669			SN74LS668 SN74LS669			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{CC}		4.5	5	5.5	4.75	5	5.25	V
High-level output current, I_{OH}				−400			−400	μA
Low-level output current, I_{OL}				4			8	mA
Clock frequency, f_{clock}		0		25	0		25	MHz
Width of clock pulse, $t_{w(clock)}$ (high or low) (see Figure 1)		20			20			ns
Setup time, t_{su} (see Figure 1)	Data inputs A, B, C, D	25			25			ns
	$\overline{ENP}$ or $\overline{ENT}$	40			40			
	$\overline{LOAD}$	30			30			
	U/$\overline{D}$	45			45			
Hold time at any input with respect to clock, t_h (see Figure 1)		0			0			ns
Operating free-air temperature, T_A		−55		125	0		70	°C

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER			TEST CONDITIONS†		SN54LS668 SN54LS669			SN74LS668 SN74LS669			UNIT
					MIN	TYP‡	MAX	MIN	TYP‡	MAX	
V_{IH}	High-level input voltage				2			2			V
V_{IL}	Low-level input voltage						0.7			0.8	V
V_{IK}	Input clamp voltage		V_{CC} = MIN,	I_I = −18 mA			−1.5			−1.5	V
V_{OH}	High-level output voltage		V_{CC} = MIN, V_{IL} = V_{IL} max,	V_{IH} = 2 V, I_{OH} = −400 μA	2.5	3.4		2.7	3.4		V
V_{OL}	Low-level output voltage		V_{CC} = MIN, V_{IH} = 2 V, V_{IL} = V_{IL} max	I_{OL} = 4 mA		0.25	0.4		0.25	0.4	V
				I_{OL} = 8 mA					0.35	0.5	
I_I	Input current at maximum input voltage	A, B, C, D, $\overline{P}$, U/$\overline{D}$	V_{CC} = MAX,	V_I = 7 V			0.1			0.1	mA
		Clock, $\overline{T}$					0.1			0.1	
		$\overline{LOAD}$					0.2			0.2	
I_{IH}	High-level input current	A, B, C, D, $\overline{P}$, U/$\overline{D}$	V_{CC} = MAX,	V_I = 2.7 V			20			20	μA
		Clock, $\overline{T}$					20			20	
		$\overline{LOAD}$					40			40	
I_{IL}	Low-level input current	A, B, C, D, $\overline{P}$, U/$\overline{D}$	V_{CC} = MAX,	V_I = 0.4 V			−0.4			−0.4	mA
		Clock, $\overline{T}$					−0.4			−0.4	
		$\overline{LOAD}$					−0.8			−0.8	
I_{OS}	Short-circuit output current§		V_{CC} = MAX		−20		−100	−20		−100	mA
I_{CC}	Supply current		V_{CC} = MAX,	See Note 2		20	34		20	34	mA

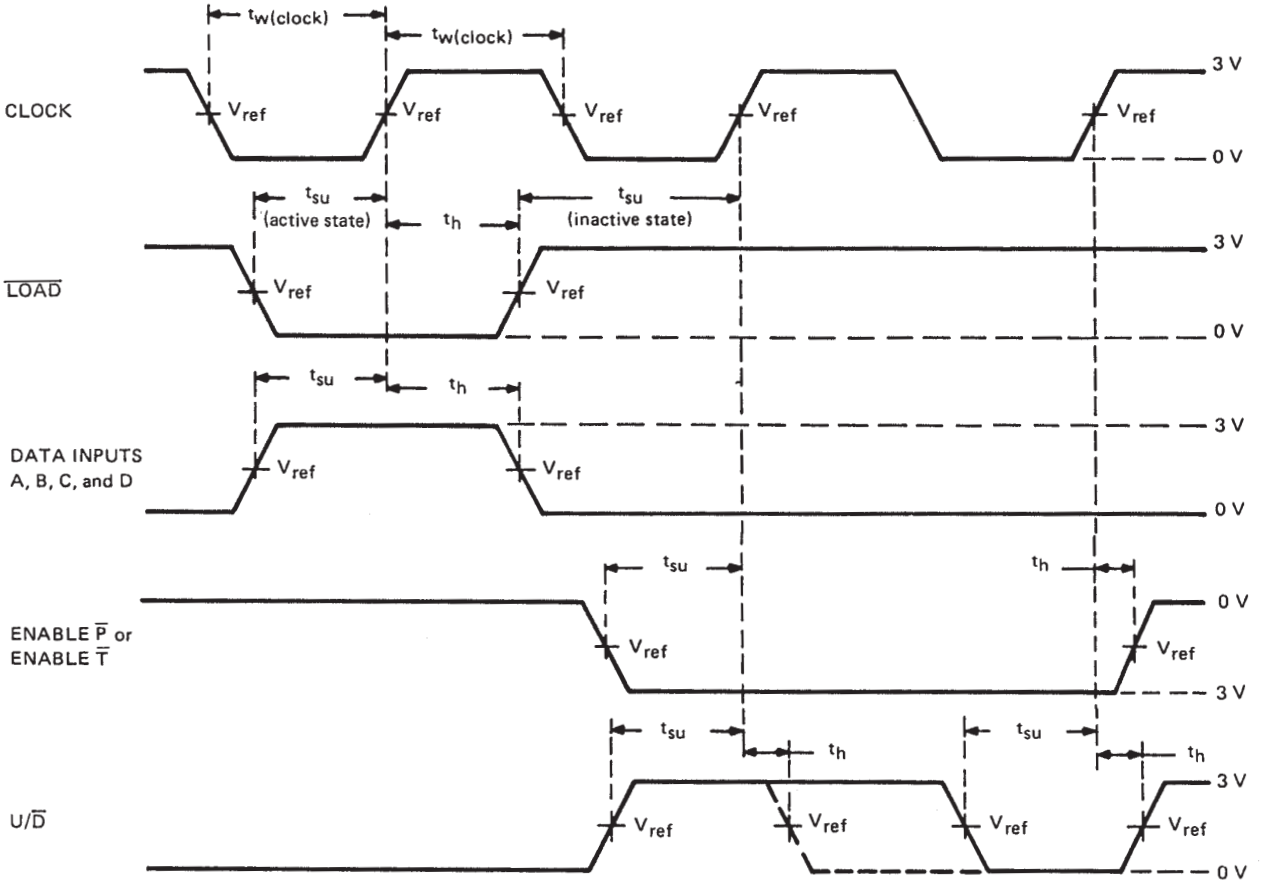
†For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡All typical values are at V_{CC} = 5 V, T_A = 25°C.
§Not more than one output should be shorted at a time, and duration of the short-circuit should not exceed one second.
NOTE 2: I_{CC} is measured after applying a momentary 4.5 V, then ground, to the clock input with all other inputs grounded and the outputs open.

switching characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER¶	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
f_{max}			C_L = 15 pF, R_L = 2 kΩ, See Figures 2 and 3	25	32		MHz
t_{PLH}	CLK	$\overline{RCO}$			26	40	ns
t_{PHL}					40	60	
t_{PLH}	CLK	Any Q			18	27	ns
t_{PHL}					18	27	
t_{PLH}	$\overline{ENT}$	$\overline{RCO}$			11	17	ns
t_{PHL}					29	45	
t_{PLH}#	U/$\overline{D}$	$\overline{RCO}$			22	35	ns
t_{PHL}#					26	40	

¶ f_{max} = Maximum clock frequency.
t_{PLH} = propagation delay time, low-to-high-level output.
t_{PHL} = propagation delay time, high-to-low-level output.
Propagation delay time from up/down to ripple carry must be measured with the counter at either a minimum or a maximum count. As the logic level of the up/down input is changed, the ripple carry output will follow. If the count is minimum (0), the ripple carry output transition will be in phase. If the count is maximum (9 for 'LS668 or 15 for 'LS669), the ripple carry output will be out of phase.

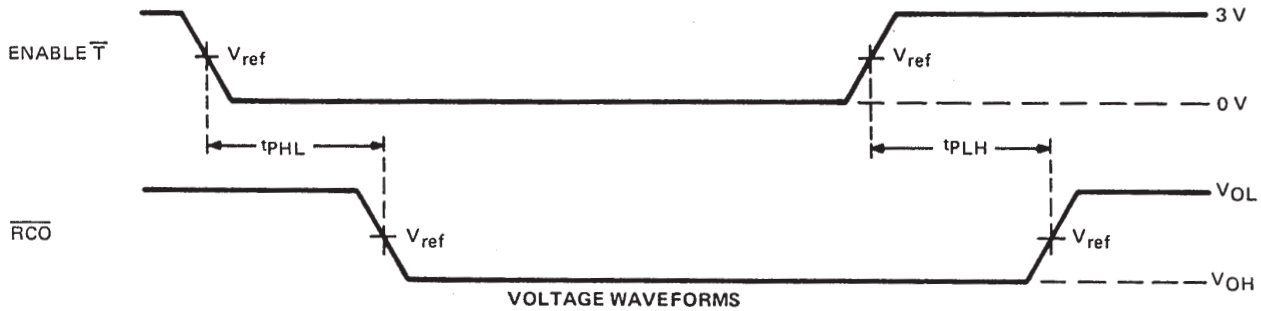
PARAMETER MEASUREMENT INFORMATION



VOLTAGE WAVEFORMS

NOTES: A. The input pulses are supplied by a generator having the following characteristics: PRR ≤ 1 MHz, duty cycle ≤ 50%, $Z_{out} \approx 50\ \Omega$; $t_r \leq 15$ ns, $t_f \leq 6$ ns.
B. $V_{ref} = 1.3$ V.

FIGURE 1–PULSE WIDTHS, SETUP TIMES, HOLD TIMES

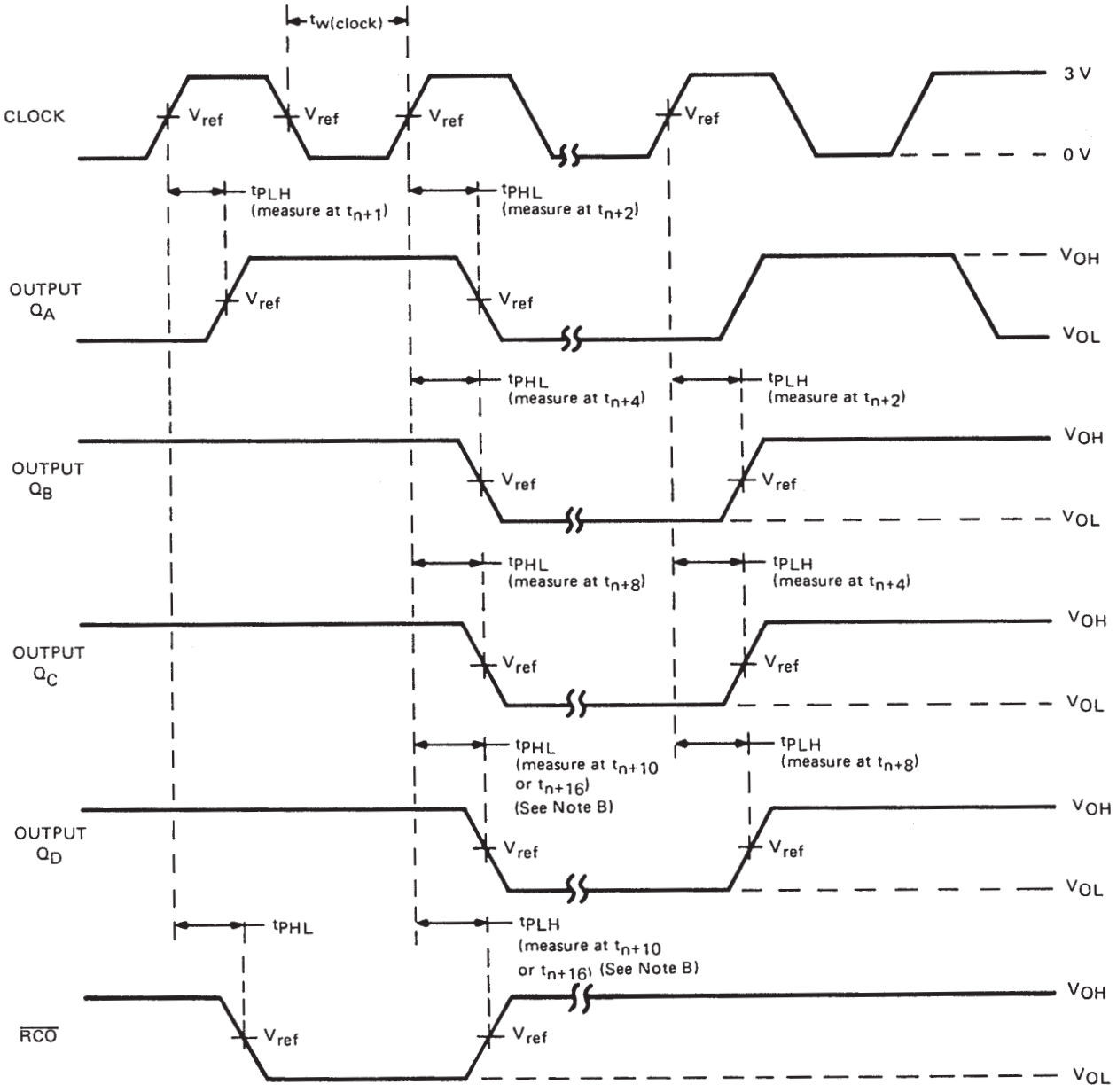


VOLTAGE WAVEFORMS

NOTES: A. The input pulse is supplied by a generator having the following characteristics: PRR ≤ 1 MHz, duty cycle ≤ 50%, $Z_{out} \approx 50\ \Omega$; $t_r \leq 15$ ns, $t_f \leq 6$ ns.
B. t_{PLH} and t_{PHL} from enable $\overline{T}$ input to ripple carry output assume that the counter is at the maximum count (Q_A and Q_D high for 'LS668, all Q outputs high for 'LS669).
C. $V_{ref} = 1.3$ V.
D. Propagation delay time from up/down to ripple carry must be measured with the counter at either a minimum or a maximum count. As the logic level of the up/down input is changed, the ripple carry output will follow. If the count is minimum (0) the ripple carry output transition will be in phase. If the count is maximum (9 for 'LS668, or 15 for 'LS669) the ripple carry output will be out of phase.

FIGURE 2–PROPAGATION DELAY TIMES TO CARRY OUTPUT

PARAMETER MEASUREMENT INFORMATION



UP-COUNT VOLTAGE WAVEFORMS

NOTES: A. The input pulses are supplied by a generator having the following characteristics: PRR ≤ 1 MHz, duty cycle ≤ 50%, $Z_{out} \approx 50\ \Omega$, $t_r \leq 15$ ns, $t_f \leq 6$ ns. Vary PRR to measure f_{max}.

B. Outputs Q_D and carry are tested at t_{n+10} for the 'LS668, and at t_{n+16} for the 'LS669, where t_n is the bit-time when all outputs are low.

C. $V_{ref} = 1.3$ V.

FIGURE 3–PROPAGATION DELAY TIMES FROM CLOCK

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